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THE TWENTIETH CENTURY ENGINEER[1]

It is essential to develop industrialism, . . . to train men so that they shall be engineers, merchants—in short, men able to take the lead in all the various functions indispensable in a great modern civilized state.

Such was the recent utterance of a distinguished American traveler in an address at the ancient Moslem University on the banks of the Nile. It reflects the sentiment prevailing in America to-day. Mr. Roosevelt held up as it were a mirror to the Egyptians, that they might see in it the reflection of American conviction relative to education. The underlying thought is, as he expressed it, that

There has always been too great a tendency in the higher schools of learning in the west (the occident) to train men merely for literary, professional and official positions; altogether too great a tendency to act as if a literary education were the only real education.

The foundation of healthy life in the state is necessarily composed of the men who do the actual productive work of the country. Among these producers the engineer is preeminent. Without him in the complex commercial life of the present, capital would lie idle, colossal manufactures would shrink to individual industries, the development of resources would cease, the earth would no longer contribute as now to the wealth of nations, and society might eventually relapse into the relation of the feudal baron and his retainers of the middle ages.

The engineer is now more than ever before an essential factor in affairs. Engi-

[1] An address delivered at the dedication of Pasadena Hall of the Throop Polytechnic Institute, Pasadena, Cal., June 8, 1910.

neering information and technical skill are in demand in many fields not heretofore requiring them. What manner of man is this present-day engineer, whose existence and work are so vital to the higher interests of society? What are the intellectual qualities that fit him for his high office, what the aptitudes that qualify him for leadership, what the supreme test of his fitness to bear on his shoulders some of the burdens of organized civil life and to lead the way toward still higher achievements? Finally, what style of intellectual training is best suited to fit him for the prodigious problems awaiting solution at his hands?

It is not necessary, even in this presence, to refrain from saying that the type of man, whom we are about to survey in his highest ethical and intellectual character, is not an artisan, a motorman, nor even an engine-driver, as useful and honorable as these callings are. Nor is it manual training or manual dexterity or mechanical skill that constitutes his claim to recognition as an invaluable contributor to progress in the twentieth century. He is rather the masterful man who unites oceans and revises the paths of commerce; who levels hills and removes mountains if they chance to be in his way; who changes the course of rivers or sends them through tunnels to generate electric light and power and to convert deserts into fruitful fields.

If modern industry demands combination and the massing of capital, combination requires the services of large-minded engineers as managers. When Cecil Rhodes appealed to the Rothschilds for capital to form the De Beers Diamond Mining Company for the purpose of uniting all the diverse and independent claims of the Kimberley diamond field, he was assured that money would be furnished on condition that they be permitted to place in charge their mining engineer as manager—Mr. Gardner Williams, who hailed from the great state of the Golden Gate. Mr. Williams substituted for the open working of the diamond mines his method of mining by vertical shafts, and horizontal tunnels into the core of the precious "blue ground" filling the volcanic pipes, which have yielded uncut diamonds to the aggregate value of more than $500,-000,000.

When the great gold-bearing reef at Johannesburg, the richest gold mining district in the world, needed a controlling genius to direct the Kaffir mines, it was John Hays Hammond, another American mining engineer, who dictated the engineering and mining policies of the Witwatersrand. Hammond adapted the method of mining the ore and winning the precious metal to the conditions existing in that great outcropping reef, forty miles in length, with the result that a low-grade conglomerate has yielded millions of gold with a fair profit to the shareholders. In large enterprises of this character success or failure turns on the trained intellect, the executive ability, and the comprehensive grasp of the controlling brain at the head.

There is no rainfall in Egypt. The burning, wind-driven sands forever face a cloudless sky. On half the city of Cairo no green thing grows and flourishes. Mosques and the splendid tombs of the Memlook sultans are surrounded by drifting sand. But for the yellow flood of Father Nile the whole of its fertile valley would be as parched as the sands about the great pyramids of El-Geezeh. I have seen the river in flood, when its turbid water stretched for miles beyond its banks to the rising ground at the feet of the Sphinx, enriching, irrigating and insuring a bountiful harvest to the stolid husbandman, who still practises the methods consecrated by

centuries of use. Nature has done much for Egypt; engineering has done no less. The *barrage* at Cairo and the stupendous dam at Assûan conserve the rich tepid flood of the Nile and pour it in golden streams over a million acres of fertile sugar-cane and cotton land. Instead of a burning, barren waste, the land of the Pharaohs has become more than ever before in history a garden of the gods. Egypt may hate England, but to Sir Colin Scott-Moncrieff, an English engineer, who raised the *barrage* at Cairo and built the Assûan dam, she owes more than she ever did in ancient times to Rameses II.

Across the Firth of Forth in Scotland stretches a massive iron bridge with two main cantilever spans, each longer than the famous Brooklyn bridge. They were pushed out horizontally from two cantilever shore arms without scaffolding or false works, and with the roadbed soaring 300 feet above the water of the Firth. M. Eiffel declared that it was in comparison an easy task to build the Eiffel tower nearly 1,000 feet high, because it is vertical and stands on a firm base; but to push out such a tower horizontally 300 feet above an arm of the sea, and to balance it during construction on the top of a tall pier, was infinitely more difficult and hazardous. This hazardous feat the late Sir Benjamin Baker accomplished, and over his monumental bridge 400 or 500 trains now pass daily. It was this same plain but resourceful engineer who designed the cylindrical ship that transported Cleopatra's needle from Alexandria to New York.

These daring, resourceful and intrepid engineers are examples of those who did their work for the most part in the last century. They are typical of a class who achieved fame and accomplished great things with but little help from the universities. They learned their lessons in the great school of experience, and arrived at success despite the lack of the early opportunities now open to the aspiring engineering student. They were not narrow specialists, but men with the broad intelligence to consider a new and difficult problem from all points of view, and to employ for its solution any method which their intellectual resources could command. They were not mere copyists, who read nothing beyond the headlines of their copy-books, nor yet mere imitators content to cull from the products of genius those that could be adapted to the problems in hand. They were rather the creators, whose edifices, built on the foundation stones hewn by others, have risen above the horizon for many lands.

If we inquire somewhat more minutely into the qualities that make for leadership in engineering, we shall find that thoroughness, originality and the habit of making all mental acquirements one's own are essential. Originality is a gift, but it may be cultivated; the two other qualities are certainly within the reach of every young man with normal mental endowments. The habit of going to the bottom of every subject investigated instead of contentment with a superficial examination is one to be assiduously cultivated. Each essay in concentrated effort makes mental fitness for still deeper levels of penetration.

Thoroughness is associated with sincerity in the conduct of public works. The greater undertakings which an engineer is called on to design and execute are not the ephemeral structures, made of "staff" and designed to house an international exhibition; they are for posterity as well as for his contemporaries. Noble examples of thorough and sincere work have come down to us from ancient times. One allows the eye to follow with admiration the long lines of aqueduct stretching across the

Roman Campagna, in large part still standing, though gnawed for centuries by the tooth of time. In the Forum in Rome is an opening into which one may descend to the uncovered Cloaca Maxima, or great drain of the imperial city. It was built long before the Christian era and was old when Paul suffered imprisonment in Rome and execution outside the gates. Huge rectangular blocks of tufa lie in perfectly level courses without cement, and through this great drain to-day runs a stream, like a small river, on its way to the yellow Tiber. This was honest work and the twentieth century engineer might well imitate it.

Then the proper assimilation of one's information is no less essential than thoroughness. It is not uncommon to observe a sort of aloofness of a man's mental attainments with respect to his powers of practical achievement. He appears to have put his acquisitions in a safety vault and lost the key. His intellectual equipment is for adornment and not for use. His collection resembles some collections of physical and engineering apparatus I have seen, well arranged from the point of view of a museum, but never used. A certain college janitor once complained in explanation of his ill health that his food didn't "suggest." This state of health is characteristic of the mental dyspeptic, who does not digest his intellectual pabulum, nor does it "suggest" any way in which it may be turned to good account.

Another quality of the great engineer is daring. The mythical Darius Green had it, but his daring was not coupled with the propelling power of an internal combustion engine; hence his story only adorns a rhythmic tale. His flying machine was not a forerunner of the aeroplane. Without this quality of daring developed to an astonishing degree the Wrights would not have amazed the world by their sustained flights, Bleriot would not have soared aloft across the English Channel, Paulhan would not have flitted from London to Manchester, nor would Curtiss have followed the silver line of the noble Hudson from Albany to New York. These men are representative enthusiasts of the aeroplane, whose intrepidity has made possible the navigation of the air.

The history of the first Hudson River tunnel at New York is one of repeated accidents, of many failures and of final success. During one of the periods of inactivity and when the enterprise halted near complete failure, Sir Benjamin Baker was brought over from England as a consulting engineer to give advice to the company. The air caissons were in a dangerous leaky condition, but Sir Benjamin must himself go down to make an examination. So he called for a volunteer to accompany him. An Irish laborer stepped forward and indicated his willingness to go. Together the two descended into the pneumatic caisson. The inspection completed, imagine their dilemma when Sir Benjamin discovered that their return was cut off by the leaky condition of the air locks. The eminent engineer said to his Irish companion that there was only one thing to do; they must bring mud in their caps, plaster over the cracks, and stop the leaks. The expedient was happily successful and the two escaped into the upper air. I heard Sir Benjamin tell the story to illustrate the devotion of the Irish laborer. After they were safely out Sir Benjamin said to his companion in danger, "Pat, why did you risk your life to go down into the caisson with me?" Pat replied, "I'll tell you, sir. Do you remember when you were building the Forth bridge and the foundation of one of the piers was going in, and you were in the pit inspecting the

work, that Mike McGinnis, Dan O'Leary and myself were dumping stone into that same pit, and dumped a load without seeing that you were below? But as good luck would have it, sir, you were not hit. And what did you do, sir? You just turned an eye up to see who had dumped the stone, but you said nothing, sir, and we were not told to go to the office for our time. And now here I am, sir; I endangered your life once, and it was only fair for me to take a risk for you when you needed it." Ah! how many unrecorded deeds of devotion stand to the credit of the common laborers, who have risked their lives, and, alas, too often lost them, in carrying out some great enterprise for the public. The engineer at the head must be the intrepid leader of intrepid men.

The engineer who devises and executes public undertakings of magnitude must always be prepared for the unexpected and therefore must be resourceful. It is not unusual to encounter difficulties not anticipated. These must be surmounted or failure is inevitable. A solution must be found without delay or great interests are imperiled. Swiss engineers are at present constructing a short-cut railway line between Lake Thun and the mouth of the Simplon tunnel. It includes a long tunnel through a mountain range. Two years ago, after this had been driven forward about a third of the whole length from either end, the cut from the south side was unexpectedly and suddenly driven into a deep cleft or fault filled with soft mud and ooze and forming the underlying filled bed of a mountain stream. Twenty-five men were overwhelmed and lost their lives. Now a tunnel could doubtless be pushed through soft material of this nature, but there was no foundation on which it might rest. Was the enterprise therefore abandoned? By no means. Starting back a short distance from the uncovered fault, the engineers ran a curve into the heart of the mountain behind the obstruction; this will join the two straight portions already completed.

A similar fault 900 feet deep and filled with sediment has been found under the bed of the Hudson at the Highlands, where the new aqueduct crosses the river. Since this is an aqueduct and not a viaduct, a different solution is possible. The tunnel is to be carried under the river as an inverted siphon with the vertical legs nearly 1,000 feet deep. If one can not remove or overcome an obstacle, one may at least go around or under it.

These enumerated qualities which make an engineer fit are intellectual. There is still another which is a supreme test of fitness for public service. It is the moral quality of honesty. Failing in this, there is no compensation. Intellectual honesty includes the characteristic of sincerity, to which allusion has already been made. Moral honesty is no less essential in any age, but especially so in these days of uncovered bribery and graft. The honest engineer's opinions are not for sale to the highest bidder. He is entitled to compensation for his judgment and his decisions, but they can not be purchased, a distinction with a marked difference.

There has never been an age when capable and honest engineering talent was more in demand than in this new century. The present-day problems in great cities, incident to the rapid introduction of new methods of transportation, of lighting and power, and of communication, are insistent for solution. They are almost hopelessly entangled with vested rights, and with class privileges, which have been recklessly given away in the past, or handed over for a secret and vicious consideration on the part of those incidentally in power. Civic

bodies and public-service commissions, thanks to such heroic leaders as Governor Hughes, are now giving expert attention to the solution of these economic problems in cities, aided by the highest engineering talent that good compensation can command. New York, Chicago and now Pittsburg are the subjects of study by such commissions, constituted either by private appointment or by legislative enactment. The engineers studying these problems must be clean-handed and honest to the core. This kind of public service is in its infancy, and the future is certain to furnish more of it for competent and clean engineers.

I have sketched rapidly the salient characteristics of the modern engineer required for the larger problems of an age in which industrial development proceeds with astounding rapidity. It is too much to expect these qualities to be displayed in a marked degree by young men just entering upon a course of study leading to a degree in engineering. It is not the mere possession of such qualities that ensures success, but the marked development of them. There are boys enough of sterling character, with originality, thoroughness, nerve and resourcefulness in the directions in which the interests of youth lie. It is the office of the enthusiastic teacher to develop the possibilities of a promising boy, to stimulate the growth of those traits that especially need nurture, and to encourage the power of initiative and self-reliance. And he shall have his reward. It comes not in the way of pecuniary compensation, but in that sweeter award of appreciation and gratitude on the part of those whose regard in after years counts for more than mere passing popularity. No greater delight comes to the worthy teacher of large experience than the success of those in whom he has taken a personal interest, and for whom he has been able to open the door of opportunity.

It is pertinent now to touch on the style of training best adapted to develop the qualities that distinguish the eminent engineer from his less fortunate fellows. What shall be the philosophy of his treatment educationally for the conservation of his undeveloped resources and the reclamation of his arid areas? These are serious issues for thousands of ambitious students who stand on the threshold of their young manhood.

The recent trend of affairs has shown too pronounced a tendency toward undue specialization in engineering practise. It is not enough that instead of the two traditional divisions of engineers in olden times, the civil and the military, there are now in practise civil, mechanical, mining, hydraulic, electrical, telegraph, telephone, sanitary, chemical, electrochemical and illuminating engineers, but the enthusiasts in these several lines are insisting that their specialties be assigned a seat in the circle of the engineering curriculum. This granted, the young collegian has either a narrow training that reduces him to the grade of an artisan, or the instruction given him is so superficial that it never strikes root and never reaches down to stir his subconscious powers. It may be sufficient for the practised eye of a Paulhan to get a vivid impression of the salient features of a landscape from the window of a railway carriage to serve as a guide in an aerial flight over the same region; but the young engineer, who gets a flitting view of the whole field of current engineering practise from the moving-picture show of a lecture-room lantern screen will have only a sorry preparation for sustained flight when he attempts to rise by the power of his own enginery.

Instead of a panoramic view of engineer-

ing practise, an interested public has the right to demand training in fundamentals and the elimination of ephemeral details that constitute a current art and not a body of permanent principles. The older culture course has its humanistic studies, consecrated by centuries of use, and a body of trained experts as teachers, who are not often drafted from institutions of learning by the superior rewards of professional life. Pure science also has its settled subjects of study—its languages, its higher mathematics and its circle of related sciences. Then too the scientific worker who has insight and becomes a discoverer enjoys a superlative satisfaction denied to men who never add to the sum of human knowledge as the results of research.

In contrast with these old-established courses, those in engineering are still indeterminate and lack a certain coherence which is the product of age. Shop work has too often been exalted above language, and laboratories have been established in imitation of a factory or a central power station. The fundamentals for general culture have been pushed aside by the onrush of machinery, and a young graduate must be able to run a steam engine and take an indicator card, even though he can not write a straight English sentence or dictate a business letter worthy to go on a post card.

Too much stress can hardly be placed on the necessity of thorough instruction in English. It is a common impression among the young that the study of one's mother tongue is a waste of time. There never was a greater fallacy. Psychologists tell us that a speech center has to be formed and developed in the brain. So far is human speech from being intuitive and automatic that we acquire it only by continuous and incessant effort. There is no tool used by the human mind requiring more polishing and taking a finer finish. Language is not an inheritance, but an acquisition. It may resemble on the one hand the crude spears or assegai of the South African Kaffirs, or on the other the flexible incisiveness of a polished Damascus blade. American college students have less facility in the use of idiomatic English than have students of the same age in the English universities. When one listens to the limpid and expressive English of an Oxford senior, and notes his large vocabulary and his facile use of it, as compared with the senior in an American college, one is prepared to admit the propriety of the distinction often drawn on the continent between English and American.

The engineering student should have sufficient acquaintance with the best masterpieces in English to give him a taste for the highest types of English prose, and enough practise in writing themes to secure for himself a clear and expressive style of composition.

The opinion of eminent engineers on the pressing need of a better use of English on the part of members of their profession is the best evidence of the neglect of instruction in English in engineering courses in the past. The acquisition of a clear, terse style is urged by them on the ground that an important feature of the modern engineer's duties is to make reports on various phases of engineering undertakings. These reports are an index of the man, and if they are defective in form or finish, the natural conclusion is that he is also deficient as an engineer.

It is scarcely necessary to insist on thorough courses in physics and mathematics as fundamental subjects for all engineers, though the former has often been pushed aside, with barely time enough for instruction in the merest elements of the subject, notwithstanding the fact that engineering

is largely applied physics. A civil engineer at the head of that department in a large technical school recently admitted that engineering students should take a course in light because of their use of optical instruments in surveys and locations, but he expressed the opinion that they had no use for the study of sound. And yet the abatement of serious and unnecessary noises in large cities is already the avowed object of several voluntary organizations. Any observant traveler, who has occasion to patronize the New York subways, will readily admit that some attention to the avoidance of noise on the part of the civil engineers who designed the subways would have been of great benefit to the patrons of that wonderful artery of travel. When the London Central was first put in service seventy-five feet below the surface, complaints and suits at law were numerous on the ground of serious vibrations transmitted to buildings overhead. These vibrations have largely been eliminated by reconstructing the electric engines to prevent their pounding the rails. Such facts as these the modern engineer would do well to heed.

An engineering course should include instruction in history and economics. The great civic and economic facts of the larger world should be a part of the engineer's outfit. His part in the world's work has close connection with those social and economic movements that are conditioned on future development; and the only guide we have for the future is the teaching of the past.

If present courses in engineering are to conform to these suggestions, some modifications in the purely technical subjects are requisite. Instruction in these may well be confined more closely to fundamental principles and to the enforcement of them by the concrete examples furnished by the exercises in the laboratory. A multitude of details do not belong in the instruction given to immature students, but to the actual work of the practising engineer. If inquiry is made of the experienced engineer from whom he got the most help in his college course, he will not mention the teacher whose instruction consisted largely of a category of details of the engineering art, but rather the one who marshaled the leading facts of the subject under general principles, brought out clearly the correlation between them, and enforced them by the work of the laboratory, which had obvious and vital connection with the instruction of the class-room.

My friends, I have seen young men develop into engineers who are now engaged in leading work in the world. They are directing large operations in telephone companies, holding influential posts in electric light and power industries, directing new enterprises destined to develop resources, superintending manufactures of large moment, and supervising construction undertaken by the Reclamation Service of the federal government. Such men as these give me great hope for the future of this institute planted in the most attractive spot in the empire of California south of the Tehachepi. This is a region abounding in undeveloped possibilities. Its water powers, its mines, its reservoirs of liquid fuel, its irrigation possibilities, coupled with a soil in which nature has been lavish in her gifts of productiveness, and its ocean shore in touch with the wealth of the orient, all combine to offer a field to the aspiring engineer unsurpassed in history and written all over with fetching inducements to noblest effort.

The young man who wishes to become a component part of this empire as an engineer will enter this institute and take a straight course, looking for no short cuts

to a degree, expecting no magician to lift him over hard work, and later to put him down softly in easy engineering positions. To all such the Throop Polytechnic Institute says, "Come this way!"

HENRY S. CARHART

MEDICAL EDUCATION IN THE UNITED STATES AND CANADA[1]

THE necessity of a reconstruction that will at once reduce the number and improve the output of medical schools may now be taken as demonstrated. A considerable sloughing off has already occurred. It would have gone further but for the action of colleges and universities which have by affiliation obstructed nature's own effort at readjustment. Affiliation is now in the air. Medical schools that have either ceased to prosper, or that have become sensitive to the imputation of proprietary status or commercial motive, seek to secure their future or to escape their past by contracting an academic alliance. The present chapter undertakes to work out a schematic reconstruction which may suggest a feasible course for the future. It is not supposed that violent measures will at once be taken to reconstitute the situation on the basis here worked out. A solution so entirely suggested by impersonal considerations may indeed never be reached. But legislators and educators alike may be assisted by a theoretical solution to which, as specific problems arise, they may refer.

This solution deals only with the present and the near future—a generation, at most. In the course of the next thirty years needs will develop of which we here take no account. As we can not foretell them, we shall not endeavor to meet them. Certain it is that they will be most effectively handled if they crop up freely in an unencumbered field. It is therefore highly undesirable that superfluous schools now existing should be perpetuated in order that a subsequent generation may find a means of producing its doctors provided in advance. The cost of prolonging life through this intervening period will be worse than wasted; and an adequate provision at that moment will be embarrassed by inheritance and tradition. Let the new foundations of that distant epoch enjoy the advantage of the Johns Hopkins, starting without handicap at the level of the best knowledge of its day.

The principles upon which reconstruction would proceed have been established in the course of this report: (1) a medical school is properly a university department; it is most favorably located in a large city, where the problem of procuring clinical material, at once abundant and various, practically solves itself. Hence those universities that have been located in cities can most advantageously develop medical schools. (2) Unfortunately, however, our universities have not always been so placed. They began in many instances as colleges or something less. Here a supposed solicitude for youth suggested an out-of-the-way location; elsewhere political bargaining brought about the same result. The state universities of the south and west, most likely to enjoy sufficient incomes, are often unfortunately located: witness the University of Alabama at Tuscaloosa, of Georgia at Athens, of Mississippi at Oxford, of Missouri at Columbia, of Arkansas at Fayetteville, of Kansas at Lawrence, of South Dakota at Vermilion; and that experience has taught us nothing is proved by the recent location of the State University of Oklahoma at Norman. Some of these institutions are freed from the necessity of undertaking to teach medicine by an endowed institution better situ-

[1] From the Report to the Carnegie Foundation for the Advancement of Teaching by Abraham Flexner.